Executive Summary

The instream public uses, outstanding characteristics, and resources (IPUOCR) of the Souhegan River were identified in a previous report. That report defined which IPUOCR were flow dependant and which were not. For the ultimate development of a water management plan for the Souhegan River, the identification of the flow dependant IPUOCR is the first step. An additional report identified those wells within 500 feet of the Souhegan River or its tributaries that induced recharge from the river along with the estimated magnitude of the induced recharge. Induced recharge is river water drawn in by a well, and this is a water withdrawal that can be included in the water management plan. The report herein describes the development of, and values for, the instream flow needs for each IPUOCR. Upon discussion with the Technical Review Committee and input from public hearings, protected instream flows (PISF) will be determined for the Souhegan River. The PISF are the flows that will protect and maintain IPUOCR entities. In order to achieve the PISF, for each individual IPUOCR, the location, description, instream flow evaluation method, and instream flow recommendations are presented.

At the start of this project, the Souhegan River designated reach was traversed in its entirety: either by boat or by foot. From this first field effort, almost 100 individual lengths of the river were identified with distinctive characteristics. Upon further field efforts, these individual lengths were combined and the Souhegan River was subdivided into eight sections (reaches) for the specific intent of developing the instream flow needs for each IPUOCR. IPUOCR were then associated with a specific reach, and the PISF subsequently developed for each. Because of similarities in the magnitude of the instream flow needs, geomorphic characteristics, and water quality, as well as a strong urge by the technical review committee to make the PISF as simplified and straightforward as possible, the eight sections were subsequently redefined as two reaches: the Upper Souhegan and the Lower Souhegan. The divide between these two reaches is just upstream of Milford, NH.

The instream flows for human-related IPUOCR may be found in Table ES1. These are all “low flow” type of needs; meaning that the river flow should exceed these values. The instream flows themselves are listed in two ways: the actual river flow in cubic feet per second (cfs) and the river flow per unit watershed area (in square miles) and reported as cfsm.

If just these human-related instream flows were to be synthesized to determine the controlling instream flow, the controlling flow would be the 4.0 cfsm for recreation in the upper Souhegan River, and in the lower Souhegan River it would be the 0.1 cfsm for pollution abatement. By meeting the controlling instream flow, all other instream flows are met. An important point to recognize with the human-related instream flow needs is that they are time invariant: the specified flow is steady and therefore the river flow should not fall below the specified instream flow value.

Instream flows were identified for fish and other aquatic life, as well as the flow dependant wildlife, vegetation, and natural/ecological communities. Because of the life cycles of flora and fauna, their instream flow needs are time dependent. Therefore the calendar year is subdivided into subperiods, known as bioperiods, in order to accommodate the individual

floral and faunal instream flow needs throughout the year. The specific time periods important to wildlife and vegetation may be found in Figure ES1, and for selected fish species in Figure ES2.

Table ES1. Human-Related Instream Flows

<table>
<tr><th colspan="5">PISF for selected Human-Related IPUOCR</th></tr>
<tr><th rowspan="2">IPUOCR</th><th colspan="4">Reach</th></tr>
<tr><th colspan="3">Upper Souhegan</th><th>Lower Souhegan</th></tr>
<tr><td>Recreation</td><td colspan="2">150 cfs; 4.0 cfsm</td><td colspan="2">Use is not dependent on Souhegan River flow.</td></tr>
<tr><td>Fishing</td><td colspan="4">Use is dependent on Souhegan River flow only to the extent that it protects the fishery resource. Fish and aquatic habitat apply.</td></tr>
<tr><td>Hydropower</td><td>~20 cfs; ~0.7 cfsm</td><td>No users</td><td>~42.2 cfs; ~0.44 cfsm</td><td>No users</td></tr>
<tr><td>Pollution Abatement</td><td colspan="3">2.4 cfs; <0.1 cfsm</td><td>9.4 cfs; <0.1cfsm</td></tr>
<tr><td>Water Supply</td><td colspan="4">Use is not dependent on Souhegan River flow</td></tr>
</table>

Besides the temporal variability of bioperiods, another difference between the instream flow needs of the human-related IPUOCR and some other IPUOCR is that along with the instream flow itself, some non-human IPUOCR also require a time duration or frequency for which the instream flow is specified. For example with the Fowlers Toad, a high flow is needed in the spring to fill oxbows and wetlands, but such flows only need to occur a few times in the spring. For some of the riverbank vegetation communities, high flows need only occur at a frequency of once every one to 10 years. Table ES2 delineates the various wildlife and vegetation instream flows. Some of these are high flow specifications (flow should exceed the value) and others are low flow specifications (flow should not go below the value).

For fish species studied on the Souhegan River, some fish species are able to tolerate a certain low river flow for one or two days, but as this low flow persists, the species may find growth, reproduction or even survival difficult. Three particular instream flows were defined for fish, each with its own duration: common flows, critical flows, and rare flows. These instream flows are developed based upon: the habitat that exists for the flow on the river, the characteristics of that habitat, and its frequency of occurrence. The common flow can be thought of as the most frequently occurring habitat in which the fish are existing in close to optimal habitat area conditions. There is a duration associated with the common flow simply because natural flow variability is one facet of making an optimal habitat, and as such, constant flow day in and day out is not the best characteristic for a natural system, but rather flow variability. The rare flow is the flow that occurs on a frequency and duration that, compared to other flows, is remarkably low (e.g. once every ten years or more) with attendant dramatic reduction in habitat availability. The critical flow is the flow that also dramatically reduces habitat but occurs on a frequency and duration significantly higher than rare (e.g.

every five to ten years). For each of these flow thresholds, two durations are defined: allowable and catastrophic. The catastrophic events occur on a decadal frequency whereas the allowable duration is that which would occur in an average year. Table ES3 identifies the fish instream flow criteria.

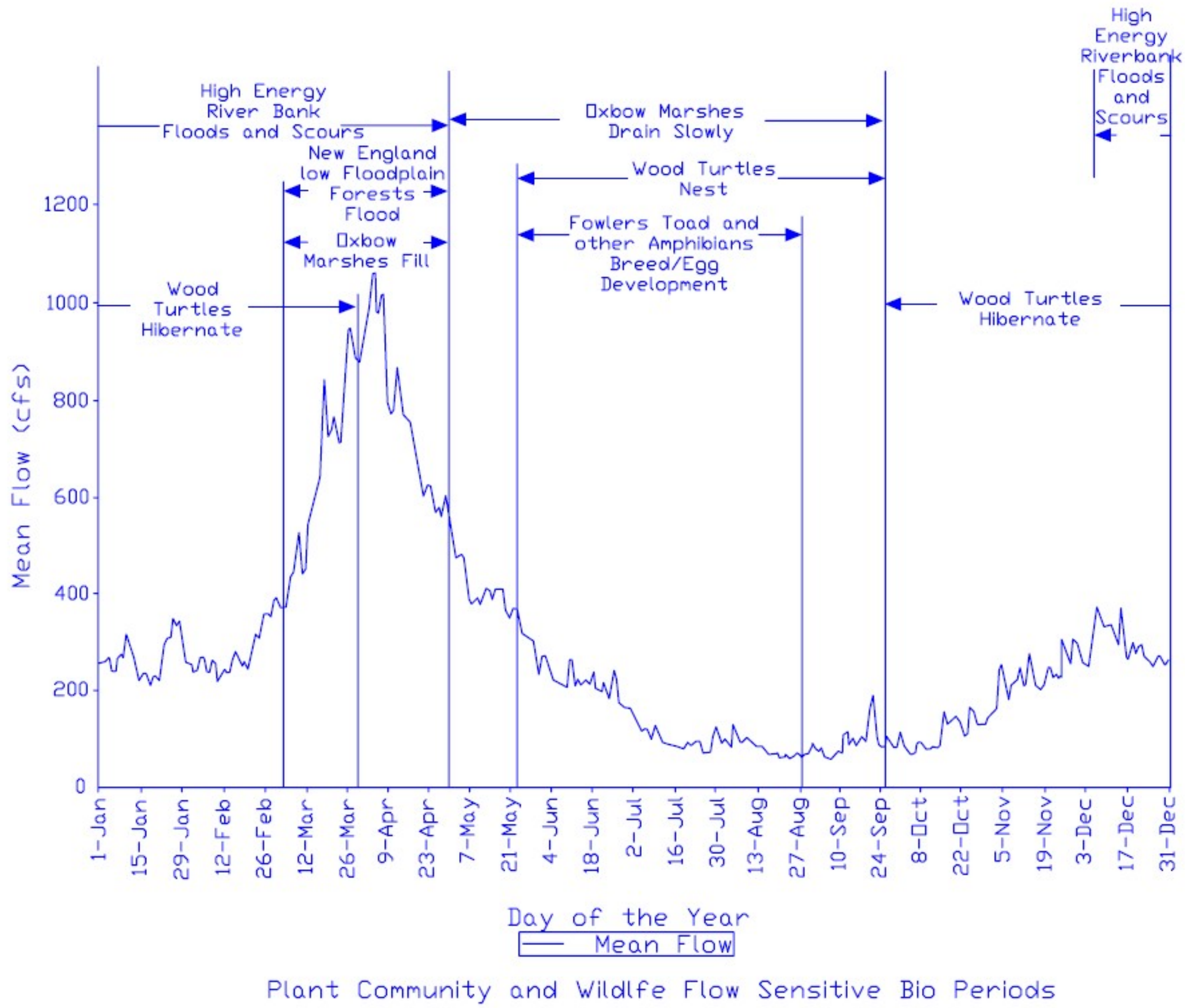

Figure ES1. Bioperiods for Rare, Threatened, and Endangered Wildlife and Natural Communities.

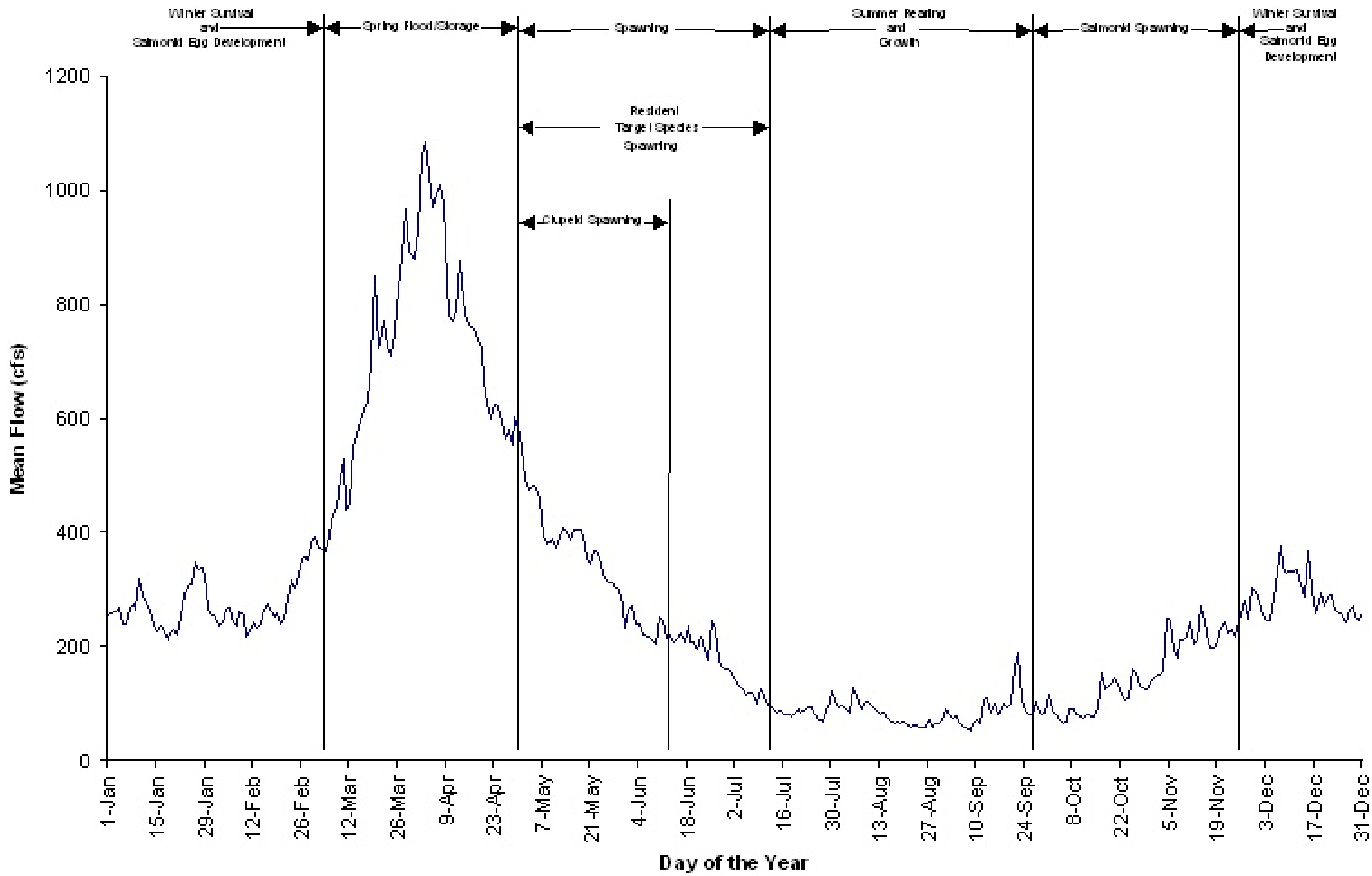

Figure ES2. Bioperiods for Selected Fish Species.

Table ES2. Wildlife and Vegetation Instream Flows

Month	J F M A M J J A S O N D
Species	**Timing and value of instream flow**
Wood Turtle (lower Souhegan only)	<5.85 cfsm > 0.97 cfsm
Fowler's Toad (lower Souhegan only)	>2.335 cfsm a few times to fill wetlands >0.175 cfsm a few times to maintain breeding pools
Wild Senna and Wild Garlic	>18.7 cfsm on a frequency of once every 2-10 years
Twisted Sedge/Fern Glade (upper Souhegan)	>0.21 cfsm >2.8 cfsm once every 1-3 years
Silver Maple Floodplain Forest (lower Souhegan only)	>11.7 cfsm once every 1-3 years
Sycamore Floodplain Forest (lower Souhegan only)	>11.7 cfsm once every 1-3 years
Oxbow/Backwater Marsh (lower Souhegan only)	>2.5 cfsm a few times to fill >0.2 cfsm

When all PISF for each IPUOCR were finalized, the PISF were synthesized to determine which was the controlling IPUOCR and instream flow. When synthesizing all of the "low flow" IPUOCR instream flows, the highest low flow PISF for all IPUOCR is the controlling PISF: by satisfying this PISF, all other PISF are met. The resulting synthesized PISF demonstrate that two human-related PISF (recreation and hydropower) are the controlling PISF. However these human IPUOCR instream flows were historically developed consistent with the existing (natural) river flow characteristics and while flow dependent, modest flow reductions by existing users have little impact to their continued value as IPUOCR. As such, it is recommended that the water management plan not be developed for the human-related instream flow needs, but rather the human-related instream flow needs continue to operate as they have traditionally. Another rationale for this posture on the human-related IPUOCR instream flow needs is because there is a lack of significant controlled storage on the Souhegan River system such that there is a general inability to meet the instream flow needs of recreation or hydropower.

It should be noted that there are water withdrawals along the Souhegan River for a variety of other human uses not mentioned above (water supply, irrigation, etc.). In general, these human uses are not flow dependent; meaning that the withdrawal quantity is not a function of river flow. Therefore these water withdrawals do not have instream flows established for them however the withdrawals themselves may be included in the water management plan.

Table ES3. Fish Instream Flows

Bioperiod	**Rearing & Growth**		**Salmonid Spawning**		**Over-Wintering**	
Approximate dates	July 15 - Sept. 30		Oct. 1 - Nov. 14		Nov. 15 - Feb. 28	
	Recommended flows		**Recommended flows**		**Recommended flows**	
Concurrent Gauge (SR#)	SR 25	USGS	SR 25	USGS	SR 25	USGS
Watershed area (mi^2)	102	171	102	171	102	171
Location	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	
Common flow (cfs)	31	103	41	184	112	188
Common flow (cfsm)	0.3	0.6	0.4	1.1	1.1	1.1
Allowable duration under (days)	30	20	30	23	N/A	35
Catastrophic duration (days)	42	40	40	40	N/A	50
Critical flow (cfs)	16	26	10	96	51	86
Critical flow (cfsm)	0.16	0.15	0.1	0.6	0.5	0.5
Allowable duration under (days)	15	15	12	12	N/A	15
Catastrophic duration (days)	35	20	30	40	N/A	30
Rare flow (cfs)	10	17	10	70	31	51
Rare flow (cfsm)	0.1	0.1	0.1	0.4	0.3	0.3
Allowable duration under (days)	5	5	10	5	N/A	5
Catastrophic duration (days)	30	10	23	10	N/A	10
Bioperiod	**Spring Flood**		**Shad Spawning**		**GRAF Spawning**	
Approximate dates	March 1 - April 30		May 1 - June 14		June 15 - July 14	
	Recommended flows		**Recommended flows**		**Recommended flows**	
Concurrent Gauge (SR#)	SR 25	USGS	25	USGS	25	USGS
Watershed area (mi^2)	102	171	102.3	171	102.3	171
Location	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**
Common flow (cfs)	112	188	215	178	24	39
Common flow (cfsm)	1.1	1.1	2.1	1.0	0.23	0.11
Allowable duration under (days)	N/A	N/A	25	15	20	17
Catastrophic duration (days)	N/A	N/A	40	25	27	25
Critical flow (cfs)	41	68	61	96	11	***239***
Critical flow (cfsm)	0.4	0.4	0.6	0.6	0.11	***1.4***
Allowable duration under (days)	N/A	N/A	10	5	10	***13***
Catastrophic duration (days)	N/A	N/A	15	10	20	***23***
Rare flow (cfs)	31	51	38	88	8	***325***
Rare flow (cfsm)	0.3	0.3	0.37	0.5	0.08	***1.9***
Allowable duration under (days)	N/A	N/A	4	5	10	***10***
Catastrophic duration (days)	N/A	N/A	7	10	15	***10***

N/A indicates that no value was prescribed due to insufficient field data
Italic values for GRAF spawning are upper limit for the instream flow

The synthesized, non-human instream flows may be found in Figures ES3 and ES4. These figures do not include the duration information of Tables ES2 and ES3.

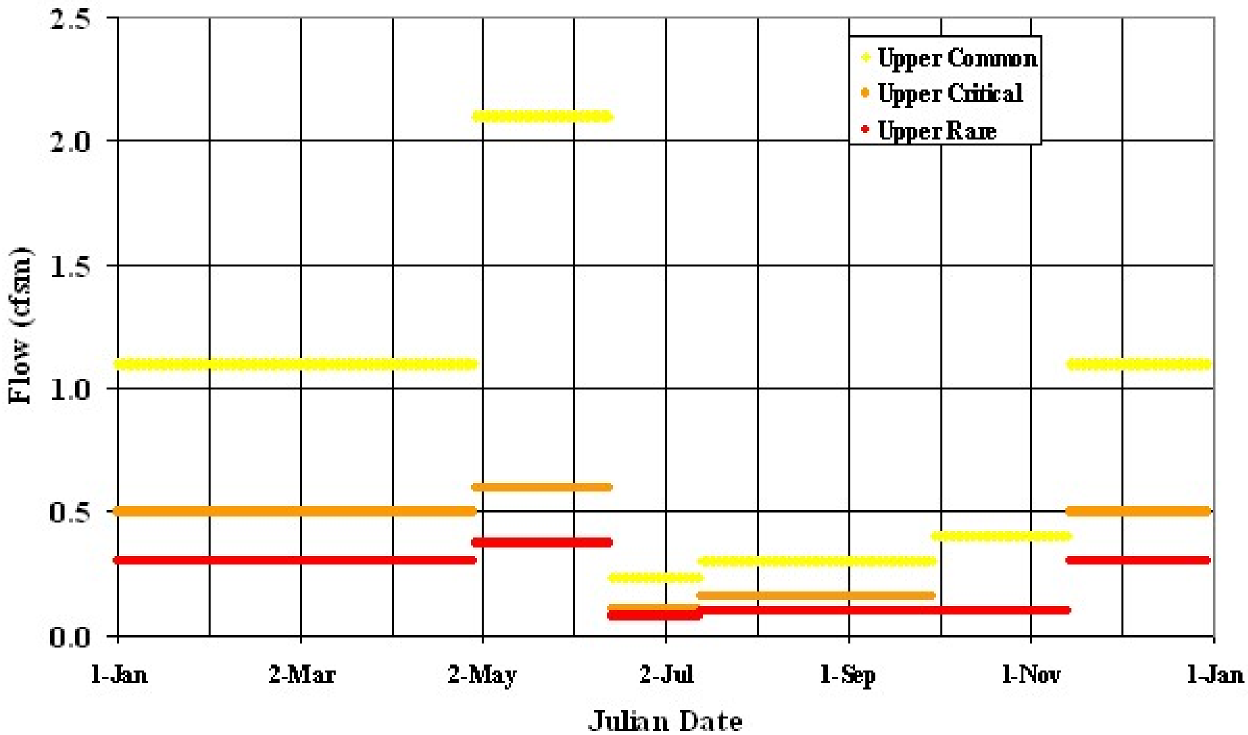

Figure ES3. Synthesized PISF for the Upper Souhegan River.

The controlling IPUOCR for the synthesized instream flows of Figures ES3 and ES4 may be found in Table ES4. As a general rule, the common instream flow needs for fish are not flows at which management strategies are warranted; rather it is the critical and rare flows that will require different levels of water management. As can be seen from Table ES4, the fish instream flow needs dominate the controlling instream flow needs.

An example of how these instream flows are used is depicted in Figure ES5 and ES6. In these figures the historic flows from calendar year 2001 are plotted along with the instream flows (PISF in the figure) for the lower Souhegan River. Figure ES5 contains all of the data and Figure ES6 magnifies the lower range of the flows. Clearly there are times when the river flow is above the protected instream flows. These are periods when no active water management is warranted. There are also periods when the river flow falls below common, critical, and/or rare instream flows. This by and of itself does not trigger active water management because attendant to most of these flows are durations. So the water management scenarios that are to be developed will use the first instance of river flow falling below the critical instream flow as the start of a clock counter. At some duration less than the catastrophic durations of Table ES3, active water management strategies will be employed.

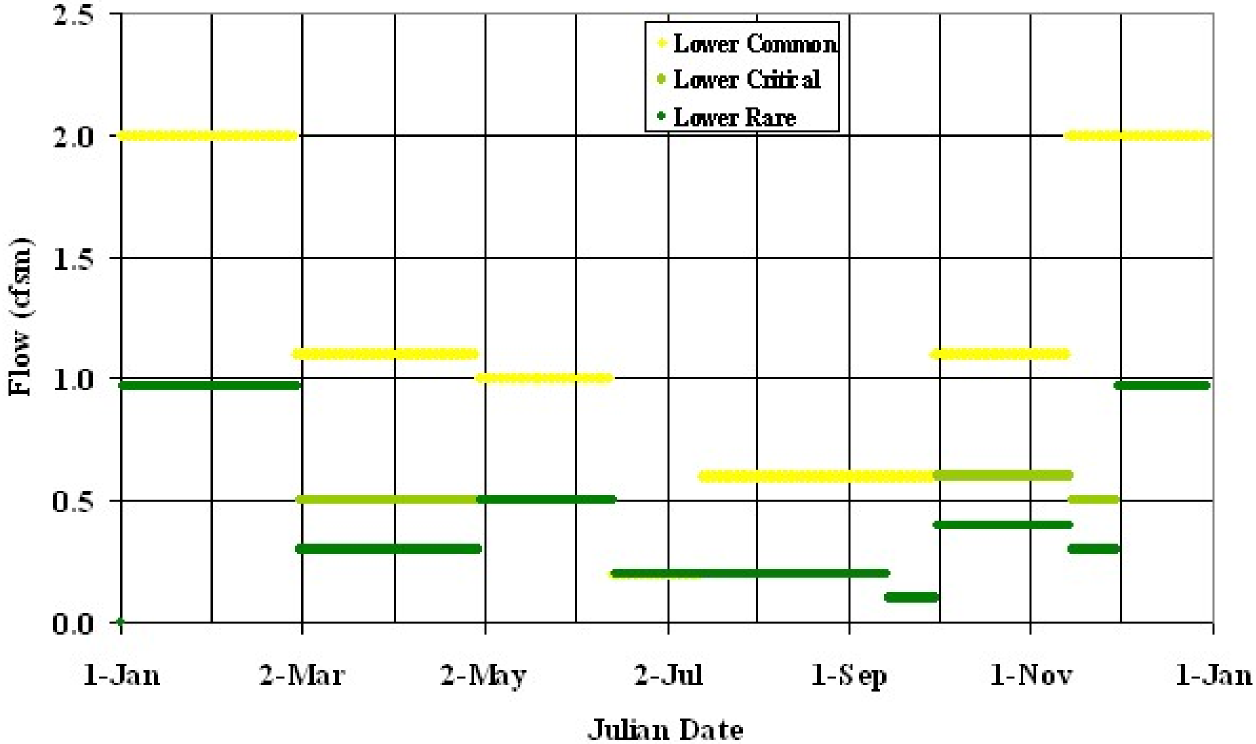

Figure ES4. Synthesized PISF for the Lower Souhegan River.

It is important to understand that in the development of the non-human instream flows, natural (in the absence of any human intervention or water use) river flows will not always meet IPUOCR needs, nor should they. The natural flow paradigm, to which this study subscribes, dictates that natural extremes, such as floods and droughts, are important features of riverine ecosystems. That is, high flows and low flows, flow variability itself, is necessary to insure that the ecosystem possesses the competence to survive the extremes: organisms in the ecosystem have the ability to adapt to the stresses.

The water management strategies must take into account how, when, and where water is used along the river in order to determine if modifications to AWU or ADO uses can improve the river flow, even temporarily to re-set the counter clock, such that river flow meets the instream flow need. The water uses along the Souhegan River are mapped in Figure ES7. In certain cases, especially in the upper Souhegan River, if the river flow falls below the instream flow value, AWU and ADO water management strategies may not affect the river flow-instream flow comparison if such AWU and ADO uses are downstream of the instream flow need location.

Table ES4. Controlling Instream Flow IPUOCR for the Souhegan River Reaches.

Time of Year	Controlling IPUOCR Critical		Controlling IPUOCR Rare	
	Upper	Lower	Upper	Lower
Jan 1 – Feb 28	Fish overwinter	Wood Turtle hibernation	Fish overwinter	Wood Turtle hibernation
Mar 1 – Apr 30	Fish spring flood	Fish spring flood	Fish spring flood	Fish spring flood
May 1 – Jun 14	Shad spawning	Shad spawning	Shad spawning	Shad spawning
Jun 15 – Jun 30	GRAF spawning	Oxbow and backwater marsh maintenance	GRAF spawning	Oxbow and backwater marsh maintenance
Jul 1 – Jul 14	GRAF spawning	Oxbow and backwater marsh maintenance	GRAF spawning	Oxbow and backwater marsh maintenance
Jul 15 – Aug 21	GRAF rearing & growth	Oxbow and backwater marsh maintenance	GRAF rearing & growth	Oxbow and backwater marsh maintenance
Aug 22 – Sep 14	GRAF rearing & growth	Oxbow and backwater marsh maintenance	GRAF rearing & growth	Oxbow and backwater marsh maintenance
Sep 15 – Sep 30	GRAF rearing & growth	GRAF rearing & growth	GRAF rearing & growth	GRAF rearing & growth
Oct 1 – Nov 14	Salmon spawning	Salmon spawning	Salmon spawning	Salmon spawning
Nov 15 – Dec 1	Fish overwinter	Fish overwinter	Fish overwinter	Fish overwinter
Dec 2 – Dec 31	Fish overwinter	Wood Turtle hibernation	Fish overwinter	Wood Turtle hibernation

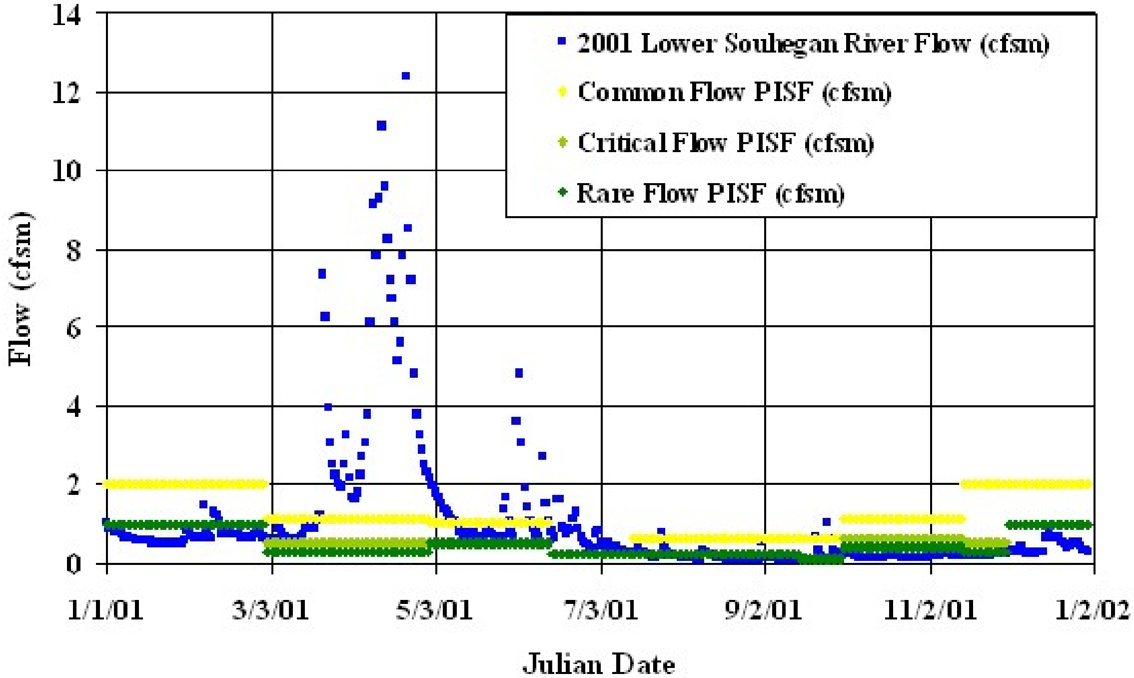

Figure ES5. Souhegan River flow in 2001 versus the lower Souhegan instream flows.

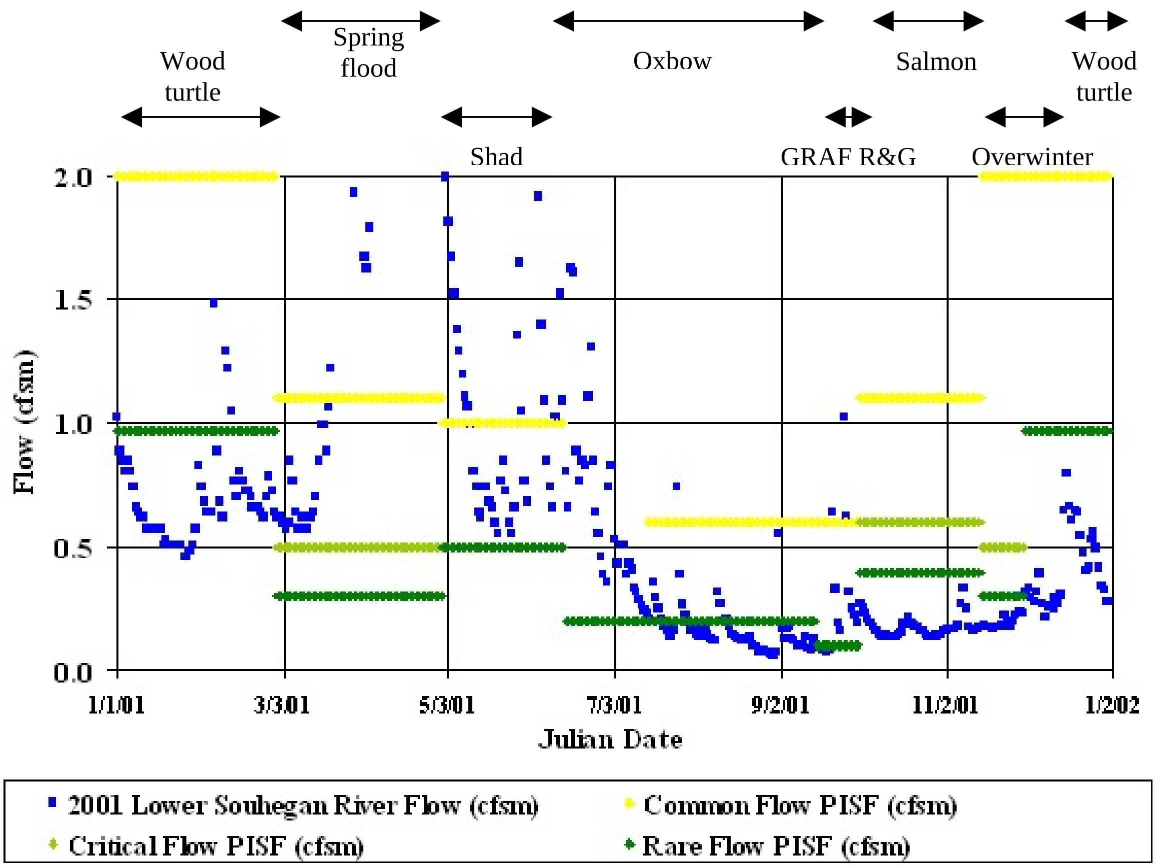

Figure ES6. Souhegan River flow in 2001 versus the lower Souhegan instream flows – magnified.

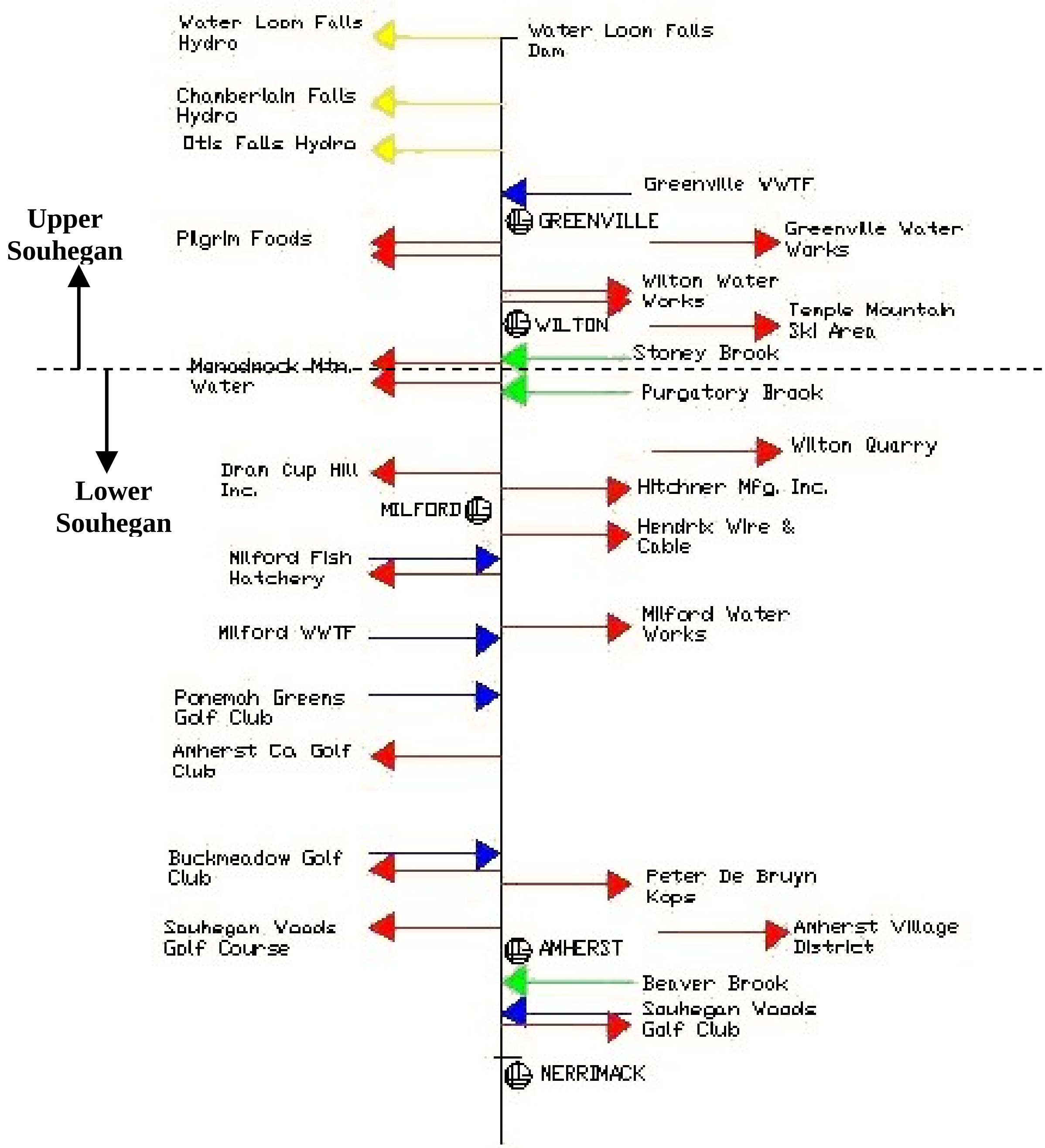

Figure ES7. Stick figure of Souhegan River and tributary withdrawals (yellow – hydropower, red - withdrawal of ground or surface water, green - major tributary or point discharge to the river, arrows not connected are on tributaries).

This study has identified that there is the opportunity to improve ecologic and fish habitat without changing flows, and this would be through stream restoration measures. Certain stream restoration measures that improve woody debris in or along the river can dramatically improve upon the existing low flow habitat without additional flow of water.

It must also be underscored that the flow of water alone does not guarantee that the instream flow needs are met: just as important is the water quality associated with that water. As this effort moves into the next stages of the development of a water management plan, the notes found in this report that address water quality (such as temperature) may offer more promising gains in meeting objectives than only insuring that more water flows in the river.